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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Energetic particle precipitation in ECHAM5/MESSy1 – Part 1: Downward transport of upper atmospheric NO_x produced by low energy electrons" *by* A. J. G. Baumgaertner et al.

Anonymous Referee #1

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In this paper, a simple, Ap-dependent parameterization of NOx deposition into the middle atmosphere due to energetic electron precipitation (EEP) is described. This parameterization, which is based on long-term NOx observations by HALOE, has been implemented in the ECHAM5/MAESSy1 model, where it represents a continuous NOx injection into the top model layer at 0.01 hPa. Model results are compared to HALOE and MIPAS NOx observations during several SH polar winters and the 2002/2003 NH winter.

The presented parameterization is interesting because it allows, in principle, for longterm simulations of atmospheric effects due to particle precipitation as it depends only on the Ap index which has been measured since 1932. However, its simplicity implies also some important limitations, particularly with respect to dynamical modulations of NOx descent between the source region and the model top boundary, which are not captured. These limitations should be identified and discussed carefully in the final revised version and possible errors should be quantified. The authors should also consider potential improvements of their parameterization concerning dynamical impacts (decent velocities and latitudinal extension of the injection area) which are discussed below in the specific comments. In the context of planned long-term simulations of global atmospheric EEP-effects, the authors should demonstrate the validity of their parameterization for several (and not only one) NH polar winter, given the more pronounced dynamical variability, there.

Further, the description of the parameterization (Section 2.3) is quite confusing and some important information is missing (see specific comments). The authors should consider a thorough revision of this section.

Specific comments:

21202 l07: "...low energy electrons (LEE) that produce NOx in the upper atmosphere." Do you mean $<$30 keV electrons producing NOx in the lower thermosphere? Please provide energy range and vertical range of energy deposition of these (LEE) electrons. It should be kept in mind that the parameterization of NOx deposition presented in this paper is based on HALOE measurements taken at 45 km which,in principle, are affected by precipitating electrons of energies up to 2MeV.

21202 l23-26: Please provide some references (or a reference to a review paper).

21206 l18: Fig. 9 of R07 shows the estimated annual NOx deposition into the stratosphere below 45 km (and not excess NOx AT 45 km). This is expressed a bit confusing in the figure caption of R07.

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Discussion Paper

21207 l01: It is not clear to me at all how excess NOx densities as expressed by Eq. 2 are derived from Fig.7 of R07. The latter figure shows the temporal evolution of excess densities at 45 km, averaged over 2-week periods, while Eq. 2 represents densities as function of annual mean Ap (averaged over May-July), i.e. one value per winter season. Or is the time dependency (Eq. 4) already used here? What is then the meaning of the quantity calculated by Eq. 2?

21207 l05: "average vertical velocity". Inside the vortex? At the top of the model (i.e. 0.01 hPa)? Please specify! In any case, the application of a constant average vertical velocity represents an important error source of the NOx flux parameterization, particularly in the NH where dynamical conditions are quite variable. This error should be estimated in terms of observed or modeled vertical velocity variations in the MLT region. Wouldn't a scaling of the c-factor by the model vertical velocity at the uppermost model layers reduce this error (assuming a correlation of vertical velocities at 0.01 hPa and above).

21207 l05 "a loss factor which accounts for transport out of the vortex as well as photochemical loss". Rather than transport out of the vortex, transport out of the polar night region is the driving factor of the NOx loss. The latter depends mainly on the latitude to which EEP- NOx is confined (i.e., the MLT "polar vortex"). Again, this latitude extension might be quite variable, particularly in the NH, so one would expect a significant variability of the "loss factor". Possible errors due to that variability should be discussed.

21208 l07: "...a serie of test simulations." Do you mean a serie of EMAC runs with variable factor c, covering the period 1992 - 2005?

21207 l8: "model g_LEE-NOX at 45 km". I assume you refer to vortex averages of excess NOx densities at 45 km as determined from EMAC simulations. If so, how did you extract the excess NOx from the background contribution? Using the same criterion as described in R07?

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21207 l16: (Eq. 4) Is the time dependence ad hoc or derived from Fig. 7 of R07? What is d, day of year? Eq. 4 appears to be appropriate only for the SH. I'm a bit confused about the offset introduced by max(0.1, ...). Is a NOx flux in the order of 10% of the maximum flux realistic during polar summer?

21207 l20-22: It is true that Funke et al. have shown that NOx enhancements are confined to the vortex. However, they have also shown in agreement with Siskind et al. (1997) that the vortex boundary was located at 30-40 S during June/July 2003, and NOT at 55 S. As stated above, the latitudinal extension is driving the reduction of the NOx flux by chemical losses. Wouldn't it be possible to confine the model flux to equivalent latitudes within the model vortex at the injection layer?

21207 l26: "monthly mean values of Ap". The flux parameterization (Eq 4) was derived under consideration of annual mean Ap (May - July for the SH and - though not stated in the text - probably Nov - Feb for the NH). Is "monthly" here a typo?

21208 l09-10: Having in mind that the vertical distribution of EEP-NOx production is not fully understood by now (i.e., mesospheric vs. thermospheric contribution, see also R07), dynamical modulation of NOx descent in the MLT region (above the top model layer at 0.01 hPa) might be an issue, particularly in the NH.The surprisingly good agreement of EMAC model results and MIPAS NOx observations (F05) for the 02/03 NH winter does not guarantee that the parameterization is generally valid in the NH. In particular, it would be interesting to see its performance in the extra-ordinary 03/04 NH winter where extremely rapid and confined descent occurred.

21209 l15-17: Latitudinal distributions of NOx derived from MIPAS (see F05) in June/July 2003 show EEP-related NOx enhancements which extend to latitudes as low as 40 S.

21210 l09: "excellent agreement with the MIPAS observations". Although agreement is generally good, there are some important differences which should be discussed. In particular, what is the reason for the model enhancements around 2500 K in August

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which do not show up in the MIPAS data?

21210 l18: "a strong downdraft of NO2...". Figure 6 shows EMAC NOx, not NO2 as stated in the text.

21210l21-22: The authors state that the parameterization works well in the NH under moderate geomagnetic activity conditions. However, geomagnetic activity variations should be captured by the Ap-dependent parameterization. It would be better to state that the parameterization works well under moderate dynamical conditions similar as those found in the 02/03 NH winter.

21211 l01: Why did you apply "average excess NOx" scaling for 1992 -2002 and "maximum excess NOx" afterward?

21212 l16-19: It is evident that NOx enhancements start later and last longer at lower altitudes. However, this does not explain the differences between model and HALOE observations shown in Figures 8 and 9, respectively, since both refer to NOx densities at 45 km.

21212 l25ff: It is not very convincing to compare model results for 2003 with those for 1996 in order to derive a EEP-related ozone depletion for 2003. Why don't you compare model ozone of EMAC runs with and without EEP? The advantage of model simulations (compared to observations) should be exploited, here.

21213 l17: monthly or 3-monthly Ap mean values?

technical

21204 l25: spell out MA

21205 l23: spell out NMHC

21206 l20: (Eq 1) shouldn't it be ...x10-3 * 1 GM?

21208 l05: typo average

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21227 Fig 10: This Figure does not show excess NOx densities, but total (excess + background) densities. "Excess" should be removed, here.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 21201, 2008.

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